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(54) DEVICE FOR X-RAY SPECTROPHOTOMETRY

(71) We, MEDINOVA AKTIEBOLAG, a Swedish corporate body, of Solna, Sweden., do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to apparatus for X-ray spectrophotometry.

According to the invention, there is provided apparatus for X-ray spectrophotometry, comprising an X-ray tube, means for feeding said X-ray tube with a high energising voltage which alternate periodically between two different levels, two absorption filters and means for inserting the filters alternately into a radiation beam emitted from said X-ray tube and arranged to insert said filters in synchronism with the periodic changes in the energising voltage, whereby to produce in said radiation beam X-rays alternating periodically between two different but substantially monochromatic wavelengths.

An embodiment of the invention will now be described by way of example only with reference to the accompanying drawings, in which:

Figure 1 is a block diagram of an embodiment of an X-ray spectrophotometry apparatus or spectrophotometer according to the invention;

Figure 2 shows a series of diagrams *a* to *e* of the voltage waveforms in the high voltage part of an X-ray generator in the apparatus. This Figure further illustrates at *f* the energy distribution at the X-radiation leaving the X-ray tube, at *g* and *h* gating signals which are obtained synchronously with the switching of filters, and at *i* and *k* electric pulses that are obtained in a detector unit — pulses which correspond to the recorded intensities of the separated wave bands; and

Figure 3 is a diagrammatic view showing an embodiment of a computing unit wherein the pulse signals according to Figure 2 are treated.

With reference to Figure 1 the numeral 1 designates a high voltage generator which feeds an X-ray tube 2. The feed occurs by means of variable voltages *a* and *b* independent of one another and illustrated in diagrams *a* and *b* of Figure 2. These voltages are stepped up through two transformers after which the voltage is doubled by means of a conventional circuit. The output voltage in the part fed by the voltage *a* is smoothed by means of two devices 13 and 14 to a curve shape according to diagram *c* of Figure 2.

Step-up transformation, zero level displacement and smoothing are attained by conventional means in the high voltage generator 1. The resultant voltage by which the X-ray tube 2 is fed is shown by diagram *e* of Figure 2. The high voltage consists of a pulsating component superposed upon an essentially constant DC voltage.

The X-ray tube 2 has a fixed water-cooled tungsten target, which emits a radiation with an energy proportional to the imposed high voltage. The energy distribution of the radiation leaving the anode is shown in diagram *f* of Figure 2. The X-ray tube emits two X-ray beams, a measuring beam towards a sensing device 6 and a reference beam towards a sensing device 6*a*. The reference beam is utilized for compensating fluctuations in the intensity of the X-ray tube 2. The measuring beam as well as the reference beam are filtered by a filter disc 3. This is driven synchronously with the mains frequency by a motor 3*a* at a speed of e.g. 1,500 revolutions per minute. The filter disc consists of four sections. Opposite sections comprise identical filters, e.g. comprising two opposite sections of thorium and the other two opposite sections of samarium. The position of the filter disc is adjusted so that the thorium filter filters the radiation during a time period when

the high voltage has a high value, while the samarium filter filters the radiation during the time corresponding to the lower and constant part of the high voltage. In this way the change of the voltage level and the filter takes place synchronously for both the reference and the measuring beam and is controlled by the mains frequency.

A sector plate 3*b* is mounted on the same shaft as the filter plate 3. An electro-optic detection device 3*c* having two transducer elements delivers pulses, illustrated in diagram *g* and *h* of Figure 2, corresponding to the respective time intervals when the high energy and low energy parts of the radiation passes to the sensing devices 6 and 6*a*. In the measuring beam there are inserted two movable measuring wedges 4*a* and 4*b* having the same absorption properties as the substances that shall be analysed, e.g. bone salts and biological soft tissues, two fixed wedges 4*e*, 4*f* and an object 5 to be examined, e.g. a part of a body. The movable wedges are governed by servo-motors 4*c* and 4*d*. The fixed wedges have the purpose of giving equal absorption over the cross section of the measuring beam. In the reference beam passing from the X-ray tube to the sensing device 6*a* there are inserted absorbers 7 and 7*a* each of which consists of the same substance as that of the respective measuring wedges 4*a* and 4*b*.

A device 8 consists of a system of electronic gates. By means of said device 8 the sensing devices 6 and 6*a* are gated so that the pulses that correspond to the transmitted X-ray intensities for the respective hard and soft energies are separated into different channels *i*, *k*, *m* and *n* (seel also diagram *i* and *k* of Figure 2). Channels *k* and *i* transmit information from the sensing device 6 while the channels *m* and *n* transmit information from the sensing device 6*a*. The intensities are recorded as a number of pulses released by the sensing devices 6 and 6*a* (see diagram *i* and *k* of Figure 2) in each half cycle, the pulses being released at a repetition rate dependent upon the radiation intensity. The recorded number of pulses are therefore independent of their amplitude.

Signals controlling the servo motors 4*c* and 4*d* are produced in a computer 9 so that the wedges 4*a* and 4*b* are adjusted in such a way that the intensities of the two wave bands transmitted to the sensing device 6 are always constant.

The apparatus operates in the following way. Before the object 5 to be examined is inserted into the beam the wedges 4*a* and 4*b* will be adjusted by means of the computer 9 so that the respective intensities of the hard and the soft X-ray radiation sensed by device 6 always remains constant and at the same time equal to the intensities of the X-ray radiation sensed by the sensing device 6*a*. When the object is inserted into the measuring beam the servo controlled wedges will be automatically withdrawn from the measuring beam to such an extent that on one hand the sum of the quantity of bone salts of one wedge 4*a* and of the object 5 is equal to the quantity of the corresponding substance 7 in the reference channel, and on the other hand the quantity of soft parts of the other wedge 4*b* and of the object 5 is equal to the corresponding substance 7*a* in the reference channel. In this way the displacement of the wedges will be a quantitative measure of the quantity of substances in the object 5. The reference beam from the X-ray tube to the sensing device 6*a* is utilized for compensating fluctuations in X-ray intensities as well as for changing the measuring range of the instrument — the dimensions of the absorbers 7 and 7*a* then being changed.

With reference to Figure 3 showing the computer, each of the four magnitudes *m*, *k*, *n* and *i* is fed into a calculator 14—17. The input is controlled by the pulse transducer 3*c* located on the filter shaft. By means of a comparator 18 the difference between the contents of the counters 14 and 15 is formed by addition of the contents of the counter 14 and the complement to the contents of counter 15. In the same way the difference between the contents of counters 16, 17 is formed in a comparator 19. These digital differences are transformed into analog values by means of D/A converters 20, 21. By means of several operating amplifiers the error signals $\Delta X_{\text{bone salt}}$ and $\Delta X_{\text{soft tissues}}$ are formed from the analog signals. The error signals $\Delta X_{\text{bone salt}}$ governs through the servo amplifier the motor belonging to the bone salt wedge so that $\Delta X_{\text{bone salt}}$ becomes zero. The error signals $\Delta X_{\text{soft tissues}}$ governs its motor in a similar way.

By the particular apparatus which has been described with reference to the drawings several advantages are attained. The most important advantage is that the signal information is transferred using pulses but is independent of pulse amplitudes. By this a high stability and freedom from drift is attained. Furthermore, the sensing devices 6 and 6*a* need not have linear or constant amplification. Moreover, great freedom is attained in selecting and separating X-ray wavelengths so that they can be chosen in an optimum manner in relation to the object to be examined.

In comparison to known apparatus, the apparatus which has been described with reference to the drawings provides X-radiations each of narrower wavelength distributions, better separation of the two wave-bands and more intense radiations. Also, the electronic circuits involved are simple and do not require close tolerances on linearity and stability and the apparatus is accurate.

WHAT WE CLAIM IS:—

1. Apparatus for X-ray spectrophotometry, comprising an X-ray tube, means for feeding said X-ray tube with a high energising voltage which alternates periodically between two different levels, two absorption filters and means for inserting the filters alternately into a radiation beam emitted from said X-ray tube and arranged to insert said filters in synchronism with the periodic changes in the energising voltage, whereby to produce in said radiation beam X-rays alternating periodically between two different but substantially monochromatic wavelengths.

2. Apparatus as claimed in claim 1, comprising detecting means arranged to operate in synchronism with the periodic changes in said energising voltage to detect the X-radiation of the two different wavelengths transmitted thereto through an object placed in said radiation beam.

3. Apparatus as claimed in claim 2, in which said detecting means includes two further filters and means for moving each said further filter so as to vary the path-length of the radiation beam there-through in dependence upon the intensity of radiation of a respective one of said two wavelengths transmitted to said detecting means, whereby to maintain the intensities of the transmitted radiation of the two wavelengths at reference levels.

4. Apparatus as claimed in claim 2 or 3, in which said detecting means is arranged to produce, in the time interval between successive voltage-changes, a train of pulses the number of which represents the intensity of radiation transmitted through said object during that time interval.

5. Apparatus as claimed in claim 3 or claim 4 when appended to claim 3, comprising a sensing device arranged to sense radiation transmitted thereto along a secondary channel through two reference filters of the same materials as the respective said further filters, and respective comparators are provided for comparing the alternate radiations transmitted through said object with the alternate radiations transmitted through said secondary channel, to produce error signals for moving said further filters.

6. Apparatus for X-ray spectrophotometry, substantially as herein described with reference to the accompanying drawings.

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2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

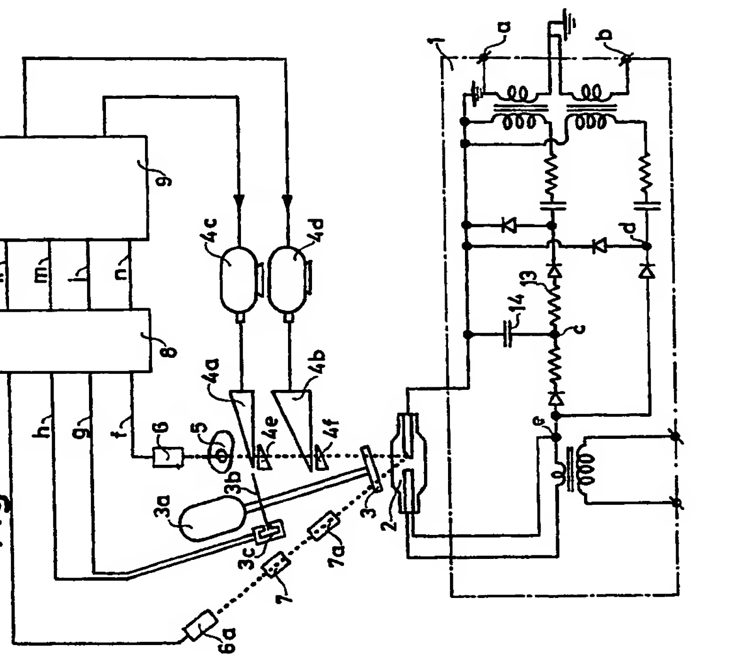

Fig.1

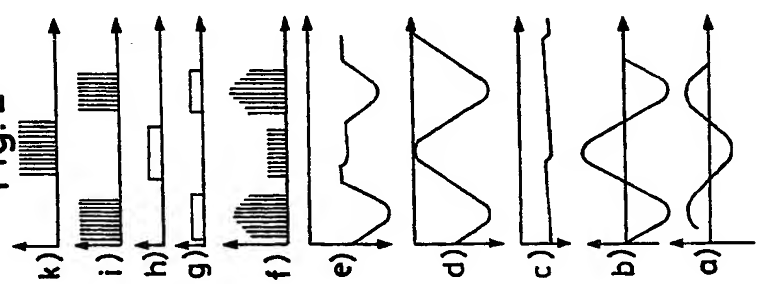

Fig.2

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Sheet 2

Fig. 3